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LOW DISPERSION SPECTRA OF GALAXIES. I. + II = Final Report

THE COMA AND VIRGO CLUSTERS

AD-74

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Abstract

Low dispersion objective-prism spectra (≅10,000 Å/mm) have been obtained of galaxies in the Coma and Virgo Clusters. Composite color indices were derived from the spectra, which when combined with magnitudes obtained from the Catalogue of Galaxies and of Clusters of Galaxies, (Zwicky et al.) allowed color magnitude diagrams for the clusters to be drawn. The differences between the diagrams for different clusters indicate that the method will prove useful in the study of the color distribution within clusters of galaxies, as well as in the identification of the bluest and reddest galaxies which might warrant further study at a higher dispersion.

Introduction

Philip and Sanduleak (1966) discussed low dispersion spectra of stars and galaxies obtained with the Warner and Swasey 24-inch Burrell Schmidt telescope. Two objective prisms were mounted so that their dispersions acted in nearly opposite directions. When the thin edges of the

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prisms were rotated 173° away from each other, spectra of very low dispersion were produced. An unfiltered Kodak N emulsion records information from [illegible]0 Å to 3500 Å. The dispersion at the blue end was about 3000 Å/mm and about 20,000 Å/mm at the red end.

After inspection of a number of such low dispersion plates taken at high galactic latitudes, we concluded that a large percentage of the galaxies on our plates formed semi-stellar spectra because of the concentration of light in their nuclei. Readers are referred to the above-mentioned article for figures illustrating the effect of changing the orientation of the prisms and typical spectra of stars and galaxies obtained.

A 90-minute ammoniated Kodak 1N emulsion reached galaxies to 15.7. The limiting magnitude of the galaxies listed in the Catalogues of Galaxies and Clusters of Galaxies (Zwicky et al 1961, 1963) is 16.0. Thus if some sort of classification scheme could be devised for galaxies that would sort them by color, according to the distribution of light within their spectra, then color-magnitude diagrams could be plotted for galaxies in a cluster. To investigate this possibility, we obtained plates of the Virgo and Coma Clusters and classified all the galaxies to the limiting magnitude of the plates according to a method which will be described next. A preliminary report on this project was given by Philip (1968).

Composite Color Index

Since one is dealing with composite spectra in the case of galaxies, one is not justified in classifying the low dispersion spectra with standard

stellar spectra having the same dispersion. We have defined a composite color index which measures the centroid of the distribution of density in the observed spectrum. The image is visually estimated to be composed of four segments bounded by the approximate wavelengths of $\lambda = 3500$, $\lambda = 4300$, $\lambda = 5000$, $\lambda = 5800$, and $\lambda = 9000$. The classifier estimates in arbitrary units the relative density of each of the four sections and computes a composite index $I = [1x(\rho_{3500-4300}) + 2x(\rho_{4300-5000}) + 3x(\rho_{5000-5800}) + 4x(\rho_{5800-9000})]/(\rho_{3500-4300} + \rho_{4300-5000} + \rho_{5000-5800} + \rho_{5800-9000})$. An index of 1.00 indicates that all the information is in the first, blue quarter of the spectrum; an index of 4.00 indicates that all the information is in the fourth, red quarter of the spectrum. The majority of the galaxies in the Coma and Virgo Clusters had indices near 3.2, equivalent to a G-type spectrum.

The Crossed-Prism Spectrum: Comparison with Other Methods of Color Analysis

A test of this classification scheme can be made by comparing the indices obtained from the crossed-prism spectra with the photometry of Tifft (1969) of galaxies in the Virgo Cluster. Tifft photometered galaxies using diaphragms of five different sizes which ranged in diameter from 10 to 64 seconds of arc. His 1-3 color corresponds to the U-B color of the UBV system. Eighteen of the galaxies in the Virgo Cluster that Tifft photometered appeared on our plates. In Figure 1 are presented Tifft's (1-3) colors plotted against our color index for these galaxies. The upper graph gives the relation for the 64" diaphragm, the lower graph the relation for the 10" diaphragm. The standard deviation of the points in the upper ... was ± 0.090 in units of the index, and in the lower graph, ± 0.075.

Thus one may conclude that our spectral index does correlate with the photoelectric colors of galaxies. The correlation is best with the colors obtained for the nuclear regions which dominate in forming the low dispersion spectra.

The crossed prism method has advantages over multicolor photographic photometry in that in one 90-minute exposure of a cluster of galaxies, approximately 100 galaxies may be recorded simultaneously under identical sky conditions for later measure. To gain the same amount of information, a four-color photographic photometric system would have to be used. The total exposure time would be greater and you would have the added problem that the exposures would be taken at different times. A disadvantage is that galaxies which have appreciable internal structure cannot be classified on our plates. This group includes those brighter galaxies which are seen edge on.

Observations

The purpose of this paper is to indicate what information can be gained from a study of crossed-prism plates of two well-studied clusters. Future papers will discuss clusters that have not been studied and will serve as surveys to locate interesting galaxies for further work.

The plate material obtained for this study is listed in Table I.

Table I

Crossed-Prism Plates
(Warner and Swasey Observatory)

Plate No.	Cluster	R.A. 1962	Dec.	Exposure	Date
6482	Virgo	12 28	6 30	45^m (Water sensitized)	3 1/2 1962
6510	Virgo	12 28	11 30	45^m (Water Sensitized)	3 3/4 1962
6509	Coma	12 57	28 12	90^m (Ammonia sensitized)	3 3/4 1962

The galaxies from Zwicky, Herzog, and Wild (1961) that fell in the area of our Virgo plates, complete to a limiting magnitude of $M_p = 14.5$ are listed in Table II. Those galaxies on the list for which we could not obtain a spectral index are indicated in the remarks section. Some galaxies were orientated edge-on and the spectrum was distorted so no classification could be made. These galaxies are noted by the term "orientation" under remarks. Some galaxy images were too diffuse to classify; these are indicated by the term "diffuse". Some galaxy images which were insufficiently stellar like because of the apparent size of the galaxy are noted by the term "amorphous". In the first column the NGC number (or if followed by an asterisk, the I.C. number) is listed, followed by the right ascension and declination for 1950. The magnitude from Zwicky et al. is found in column four and the ~~spectral~~ composite index in column five. Similar data for the Coma Cluster is given in Table III. All galaxies to mag. = 15.5 are listed from Zwicky and Herzog (1963). Those galaxies without an index will be followed by a remark as in Table II. Each galaxy was classified independently by each author and the average index was entered in the tables. The internal probable error was ± 0.08.

Color-Magnitude Diagrams

The color-magnitude diagrams for the Virgo and Coma clusters are shown in Figures 2 and 3. In these diagrams we have plotted our composite color index against the photographic magnitudes given in Tables II and III. The Coma Cluster is a standard example of a regular cluster, while the Virgo Cluster is a standard example of an irregular cluster. Therefore, some difference might be expected between the two color-magnitude diagrams. The major difference that can be seen is in the magnitudes of those galaxies which are bluer or redder than the mean color of galaxies in the cluster. The dispersion in colors is greater in Virgo than in Coma, undoubtedly because of the

TABLE 2

GALAXIES IN THE VIRGO CLUSTER

N.G.C. OR I.C. NUMBER	R.A. (1950)	DEC.	MAG.	INDEX	REMARKS
4299	12 19.1	11 47	12.8	--	DIFFUSE
4313	12 20.1	12 05	13.2	--	ORIENTATION
4330	12 20.7	11 39	14.0	--	ORIENTATION
4334	12 20.8	7 45	14.9	3.14	
4339	12 21.0	6 21	13.1	3.09	
3256*	12 21.1	7 20	13.0	3.19	
4342	12 21.1	7 14	13.5	3.34	
3258*	12 21.2	12 45	14.3	--	TOO FAINT
3260*	12 21.4	7 23	14.5	3.17	
4351	12 21.5	12 29	13.5	2.43.	
4352	12 21.5	11 30	14.0	3.15	
3268*	12 21.6	6 53	14.2	2.22	
4365	12 21.9	7 35	11.5	3.00	
4371	12 22.4	11 59	12.1	3.17	
4370	12 22.4	7 43	14.1	3.15	
4374	12 22.5	13 10	10.8	3.11	
4380	12 22.5	10 17	13.4	3.39	
	12 23.1	7 30	14.4	--	TOO FAINT
4387	12 23.2	13 05	13.2	3.19	
4386	12 23.3	12 56	12.2	3.34	
4390	12 23.3	10 44	13.7	-	DIFFUSE
4402	12 23.6	13 23	13.6	-	ORIENTATION
4406	12 23.7	13 14	10.9	3.14	
789*	12 23.8	7 44	15.2	2.90	
4413	12 24.0	12 53	13.6	2.85	
4415	12 24.1	8 42	14.2	-	DIFFUSE
4417	12 24.2	9 51	12.2	3.07	
4416	12 24.2	8 12	13.5	2.80	
4423	12 24.6	6 09	14.4	-	DIFFUSE
4424	12 24.7	9 42	13.1	-	ORIENTATION
4425	12 24.7	13 01	13.3	3.20	
4429	12 24.9	11 23	11.4	3.23	
4430	12 24.9	6 32	13.4	-	DIFFUSE
4431	12 24.9	12 39	14.[illegible]	3.11	
4434	12 [illegible]	[illegible]	13.[illegible]	[illegible]	
4438	12 25.2	13 17	12.0	3.22	

4435	12 25.2	13 21	11.9	3.07	
4440	12 25.4	13 34	13.0	3.19	
4442	12 25.5	10 05	11.2	3.17	
4445	12 25.7	9 43	13.7	-	ORIENTATION
4451	12 25.1	9 32	13.4	-	DIFFUSE
4452	12 26.2	12 02	13.1	--	ORIENTATION
4458	12 26.4	13 31	13.3	3.09	
4461	12 26.5	13 28	12.2	3.17	
4464	12 26.8	9 26	13.5	2.96	
4469	12 26.9	9 01	12.6	3.13	
3414*	12 26.9	7 03	14.2	-	DIFFUSE
4470	12 27.0	8 06	12.9	-	AMORPHOUS
4472	12 27.2	9 16	10.2	3.00	
4473	12 27.3	13 42	11.2	3.14	
4477	12 27.5	13 55	11.9	3.17	
4476	12 27.5	12 37	13.3	3.01	
3427*	12 27.6	11 03	14.2	3.25.	
4478	12 27.8	12 36	12.2	3.25	
4479	12 27.8	13 51	13.9	3.13	
4483	12 28.1	9 17	13.4	3.11	
4486	12 28.3	12 40	10.4	3.12	
4488	12 28.3	8 38	13.8	3.11	
	12 28.4	12 33	11.2	2.65	
4491	12 28.4	11 46	13.7	--	ORIENTATION
4492	12 28.4	8 21	14.1	3.09	
4497	12 29.0	11 54	13.8	--	ORIENTATION
4503	12 29.6	11 27	12.4	3.22	
4506	12 29.7	13 42	14.2	--	DIFFUSE
3481*	12 30.4	11 41	14.8	3.23	
4518	12 30.6	8 07	15.0	3.12	
4519	12 31.0	8 55	12.8	2.89	
4522	12 31.1	9 26	13.6	--	AMORPHOUS
3499*	12 31.2	11 16	14.5	--	ORIENTATION
4526	12 31.5	7 58	10.6	3.09	
4528	12 31.6	11 36	12.9	3.09	
4535	12 31.8	8 28	11.1	2.89	
4532	12 31.8	6 45	12.3	--	DIFFUSE
4531	12 31.8	13 21	13.3	--	DIFFUSE
3521*	12 32.1	7 26	14.2	--	DIFFUSE
4543	12 32.8	6 23	14.6	3.04	
4550	12 33.0	12 30	12.5	3.11	
4552	12 33.1	12 50	11.1	3.20	
4551	12 33.1	12 32	13.1	3.12	
4564	12 33.9	11 43	12.2	3.05	
4567	12 34.2	11 [illegible]	12.[illegible]	3.04	
[illegible]	12 34.0	11 31	[illegible]	3.[illegible]	
4570	12 34.3	7 [illegible]	11.[illegible]	[illegible]	
4569	12 34.3	13	11.8	2.76	

4578	12 35.0	9 50	12.9	3.12	
4580	12 35.2	5 38	13.1	--	DIFFUSE
4579	12 35.2	12 05	11.5	3.15	
4584	12 35.6	13 23	14.2	3.14.	
4591	12 36.7	6 17	14.1	2.81	
3631*	12 37.3	13 15	14.5	2.91	
4596	12 37.4	10 27	12.4	3.11	
4606	12 38.5	12 11	12.7	3.11	
3653*	12 38.7	11 40	14.7	3.17	
4612	12 39.0	7 35	12.9	3.11	
4621	12 39.5	11 55	11.0	3.17	

TABLE 3

GALAXIES IN THE COMA CLUSTER

N.G.C. OR I.C. NUMBER	R.A. (1950)	DEC.	MAG.	INDEX	REMARKS
4715	12 47.4	28 5	15.4	3.11	
4721	12 47.8	27 36	15.2	3.30	
47[illegible]6	12 48.0	27 43	15.6	3.15	
	12 48.3	28 3	14.[illegible]	3.19	
	12 48.5	27 39	15.5	-	DIFFUSE
4723	12 48.7	29 4	14.9	3.20	
	12 48.8	27 23	15.3	3.25	
4745	12 49.9	27 42	15.4	3.24	
	12 49.6	27 18	15.4	3.13	
	12 49.6	27 51	15.5	3.20	
831*	12 50.2	26 45	15.5	3.29	
	12 50.3	27 40	15.3	2.87	
	12 50.4	28 39	14.5	3.20	
	12 50.7	27 21	15.0	3.14	
832*	12 51.4	26 43	15.[illegible]	3.18	
	12 51.4	29 15	15.6	3.30	
	12 51.6	27 25	14.9	-	EXTREMELY DIFFUSE
4787	12 51.7	27 20	15.5	3.32	
4788	12 51.8	27 35	15.4	3.21	
4789	12 51.9	27 20	13.3	3.21	
	12 52.1	28 39	15.5	3.12	
4793	12 52.2	29 12	12.3	3.20	
	12 52.2	27 12	15.6	3.23	
4798	12 52.5	27 41	14.3	3.46	
	12 52.5	28 41	15.7	3.19	
	12 53.0	28 5	15.5	3.32	
	12 53.0	28 44	15.7	3.05	
4807	12 53.1	27 47	14.4	3.21	
	12 53.1	27 56	15.3	3.22	
3900*	12 53.3	27 31	14.8	3.05	
	12 53.7	27 [illegible]	15.3	-	PLATE FLAW
481[illegible]	12 5[illegible]	28 1	14.8	3.12	
	12 54.[illegible]	26 [illegible]	15.3	3.18	
	12 54.[illegible]	28 1	1[illegible].5	3.[illegible]4	
4821	12 54.1	27 13	15.0	3.21	
4819	12 54.1	27 15	14.0	3.14	

3913*	12 54.1	27 33	15.5	-	DIFFUSE
	12 54.1	28 6	15.6	3.19	
4827	12 54.3	27 26	14.1	3.49	
4828	12 54.3	28 17	15.4	3.14	
	12 54.4	27 22	15.7	3.49	
835*	12 54.5	26 45	14.9	-	DIFFUSE
	12 54.5	27 10	15.1	2.88	
	12 54.5	29 12	15.2	3.05	
	12 54.6	29 19	15.4	3.16	
	12 54.8	29 15	14.8	3.07	
	12 54.8	27 44	15.0	3.26	
4839	12 55.0	27 46	13.6	3.15	
	12 55.0	27 49	15.3	3.16	
4[illegible]1	12 55.1	28 45	13.5	3.18	DOUBLE SYSTEM IN HALO
4841	12 55.1	28 45	13.5	3.23	DOUBLE SYSTEM IN HALO
4840	12 55.1	27 53	14.8	3.23	
837*	12 55.1	26 46	15.4	3.13	
	12 55.1	28 28	15.4	3.33	
4842	12 55.2	27 45	14.9	3.16	
	12 55.2	27 7	15.5	3.13	
	12 55.3	28 9	15.3	3.23	
	12 55.3	28 6	15.7	3.19	
	12 55.4	28 27	15.5	3.15	
	12 55.6	27 8	15.2	-	OVERLAP
	12 55.6	27 11	15.5	3.23	
	12 55.6	28 5	15.7	3.22	
4848	12 55.7	28 31	14.2	-	DIFFUSE
838*	12 55.8	26 40	14.5	3.27	
	12 55.8	29 13	15.2	3.29	
	12 55.8	28 59	15.5	-	DIFFUSE
	12 55.8	28 24	15.5	3.11	
	12 55.9	29 24	15.0	3.15	
4851	12 55.9	28 25	15.2	3.20	OVERLAP
4850	12 56.0	28 14	15.3	3.03	
	12 56.1	28 17	15.0	3.15	
	12 56.1	27 31	15.4	2.43	
4853	12 56.2	27 51	14.2	3.01	
	12 56.2	27 22	15.3	3.18	
	12 56.2	27 26	15.4	2.80	
3943*	12 56.2	28 23	15.6	3.21	
4854	12 56.4	27 57	15.2	3.20	
3945*	12 56.4	28 5	15.3	3.13	
3942*	12 56.5	28 6	14.9	-	DIFFUSE
3947*	12 5[illegible]	[illegible] 4	15.5	3.28	
4859	12 56.6	27 3	14.8	3.1[illegible]	
	12 56.6	28 30	15.3	3.31	
4858	12 56.6	28 23	15.5	2.95	
4860	12 56.7	28 24	14.7	3.20	

	12 56.7	27 55	15.1	2.95
3959*	12 56.7	28 3	15.2	3.27
3960*	12 56.7	29 8	15.5	3.11
3957*	12 56.7	28 2	15.6	3.15
3953*	12 56.7	28 16	15.6	3.21
4864	12 56.8	28 15	14.8	3.17
	12 56.8	27 40	15.4	3.44
4867	12 56.8	28 19	15.5	3.16
	12 56.8	28 21	15.6	3.24
3963*	12 56.8	28 3	15.7	3.10
4865	12 56.9	28 21	14.6	3.18
4869	12 57.0	28 11	14.9	3.17
4871	12 57.0	28 14	15.1	3.21
3976*	12 57.0	28 7	15.5	3.26
3973*	12 57.1	28 9	15.2	3.15
4873	12 57.1	28 15	15.4	3.12
4874	12 57.2	28 14	13.7	3.23
3990*	12 57.2	29 10	15.0	3.18
4872	12 57.2	28 13	15.3	3.11
3991*	12 57.2	29 12	15.5	3.08
4875	12 57.2	28 11	15.6	3.26
	12 57.2	28 54	15.6	2.95
4876	12 57.3	28 11	15.1	3.07
	12 57.3	27 58	15.1	3.18
	12 57.3	28 5	15.6	3.25
	12 57.3	28 12	15.7	3.10.
3998*	12 57.4	28 15	15.6	3.26
4893	12 57.5	28 18	15.2	3.28
4892	12 57.6	27 10	14.7	3.16
4881	12 57.6	28 31	14.7	3.23
4889	12 57.7	28 15	13.0	3.20
4886	12 57.7	28 15	15.1	3.15
	12 57.7	28 8	15.6	3.13
4011*	12 57.7	28 16	15.6	3.19
4012*	12 57.7	28 21	15.7	3.23
	12 57.8	29 6	15.4	3.25
	12 57.8	28 26	15.6	3.10
4021*	12 57.8	29 19	15.6	3.15
4895	12 57.9	29 23	14.3	3.18
4898	12 57.9	28 14	14.7	3.22
4894	12 57.9	28 14	15.7	3.16
	12 58.0	26 56	15.2	3.08
4032*	12 58.0	29 8	15.4	3.18
403[illegible]*	12 58.0	[illegible]	[illegible]	3.22
[illegible]	12 58.1	[illegible]	[illegible]	[illegible]
	12 58.1	27 [illegible]	15.4	[illegible]
842*	12 58.2	29 17	14.6	3.11

4040*	12 58.2	28 20	15.1	3.05
	12 58.2	28 25	15.7	3.13
4906	12 58.3	28 12	15.2	3.12
4042*	12 58.3	28 14	15.5	3.13
	12 58.3	28 36	15.6	3.10
4041*	12 58.3	28 16	15.7	3.19
4907	12 58.4	28 26	14.6	3.10
4045*	12 58.4	28 22	15.1	3.27
	12 58.4	27 40	15.5	3.32
4911	12 58.5	28 4	13.7	3.37
4051*	12 58.5	28 17	14.8	3.13
	12 58.5	28 38	14.9	3.15
4908	12 58.5	28 19	14.9	3.19
	12 58.6	28 10	15.6	3.42
	12 58.7	28 5	15.7	3.12
4919	12 58.9	28 4	14.9	3.25
4921	12 59.0	28 8	13.7	3.15
4922	12 59.0	29 35	14.2	3.20
4923	12 59.1	28 6	14.7	3.23
	12 59.1	28 57	15.3	3.26
843*	12 59.2	29 24	14.8	3.38
4088*	12 59.4	29 19	14.8	3.15
	12 59.4	28 22	15.2	3.14
	12 59.4	28 9	15.5	3.24
4926	12 59.5	27 53	14.1	3.20
4927	12 59.6	28 16	14.8	3.23
	12 59.6	28 3	15.4	3.09
	12 59.7	29 31	14.9	3.27
	12 59.7	27 55	15.1	3.03
	12 59.8	28 29	15.5	2.95
	12 59.8	28 40	15.5	3.16
	13 0.0	28 30	15.2	3.08
	13 0.0	28 32	15.7	3.11
4106*	13 0.2	28 22	15.5	3.12
4929	13 0.3	28 18	14.9	2.98
	13 0.3	28 39	15.6	3.29
	13 0.4	28 7	15.4	3.23
4111*	13 0.5	28 20	15.7	3.16
4931	13 0.6	28 17	14.4	3.17
	13 0.6	26 47	15.7	3.06
	13 0.8	28 50	15.2	2.96
4934	13 0.9	28 17	15.0	3.44
	13 1.0	26 49	15.5	3.33
4943	13 1.4	28 21	15.6	3.23
[illegible]	13 1.5	[illegible]	[illegible]	3.12
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	13 1.8	28 31	15.[illegible]	3.24
	13 2.0	29 5	15.3	2.86

	13	2.0	26 56	15.3	3.11	
	13	2.0	27 34	15.5	-	TOO FAINT
4952	13	2.6	29 23	13.6	3.02	
4957	13	2.5	27 50	14.2	3.19	
	13	3.0	29 34	15.5	3.23	
4961	13	3.3	28 00	13.5	3.12	
	13	3.6	29 33	15.0	3.18	
	13	3.6	28 51	15.5	3.25	
4966	13	3.9	29 20	13.9	3.16	
	13	4.2	29 6	15.0	-	DIFFUSE
4971	13	4.5	28 45	15.0	3.13	
	13	4.8	28 18	15.5	3.09	
	13	5.0	26 59	15.5	-	TOO FAINT
	13	5.2	27 45	15.7	3.25	
	13	5.6	28 58	15.4	3.11	
	13	5.8	27 46	15.4	3.16	
4983	13	6.0	28 35	14.9	3.44	

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greater homogeniety in morphological types within Coma, i.e., a large preponderance of elliptical galaxies. In the Coma Cluster, the brightest two magnitudes all have about the same color, whereas in the Virgo Cluster the brightest galaxies range in index from 3.95 to 2.20. In the Coma Cluster, the range in the index is not as great and the scatter in the color-magnitude diagram does not appear until a magnitude of 15, about 2 1/2 magnitudes fainter than the brightest galaxy.

Another feature of clusters that can be studied is the possible correlation of color with position within the cluster. In the Virgo Cluster, the bluest and reddest galaxies did not show a preference for any part of the cluster; each color group is scattered at random. NGC 4568, with an index of 3.95, is the reddest galaxy found so far during this survey and would be an interesting object for work at a higher dispersion. No separation was apparent in the color-magnitude diagram of galaxies of different morphological type. In Figure 1 there was a tendency for spirals to fall below the mean relation and ellipticals to fall above.

In the Coma Cluster, as shown in Figure 4, the bluest galaxies seem to be more concentrated to the center of the cluster than do the reddest galaxies. Hood (1968) has already noted that there is a tendency for the color index to decrease with decreasing luminosity in the very central regions of the Coma Cluster.

While the crossed-prism spectral index is a coarse measure of color, the method proves to be useful as a survey technique in identifying the bluest and reddest galaxies in the nearer clusters of galaxies. Very red galaxies may be the result of internal reddening in edge on galaxies, as well as indicative of a strong M star population. The color-magnitude

diagrams that can be plotted from the index and magnitudes from the Zwicky catalogues give an indication of the type of cluster, regular or irregular.

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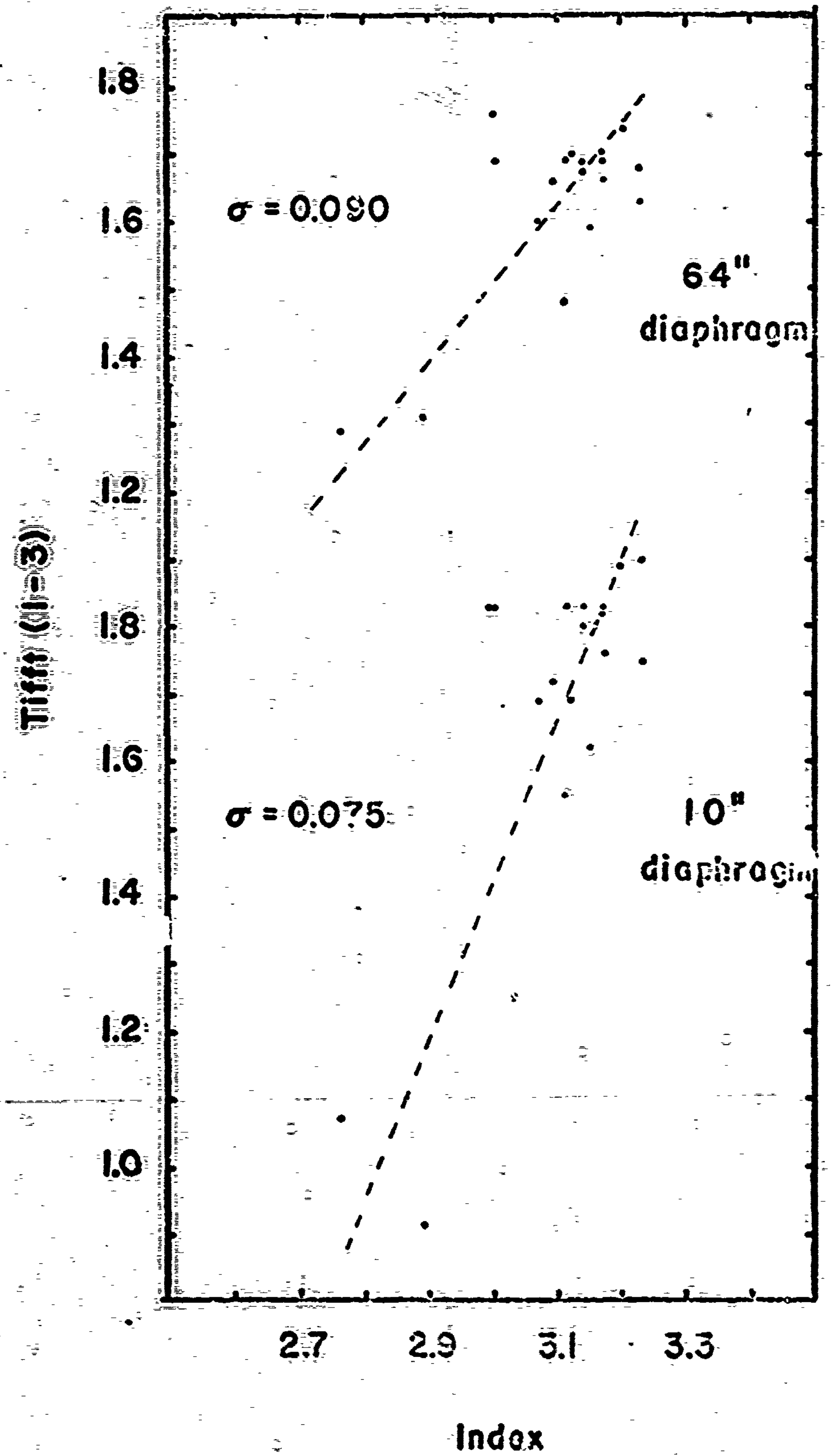
Titles for Figures

Fig. 1 Tifft's (1-3) photoelectric colors versus the spectral index for 18 galaxies in the Virgo Cluster. The correlation is best for the 10" diaphragm (lower graph).

Fig. 2 Color-magnitude diagram for the galaxies measured in the Virgo Cluster.

Fig. 3 Color-magnitude diagram for the galaxies measured in the Coma Cluster.

Fig. 4 The location of the reddest and bluest galaxies in the Coma Cluster of galaxies. Galaxies with an index >3.21 are plotted as solid triangles; galaxies with an index <2.99 are plotted as hollow circles. Solid circles mark the positions of galaxies with $3.00 \leq$ index ≤ 3.20. In the central square, only the red and blue galaxies are plotted. (Map taken from Zwicky and Herzog, 1963).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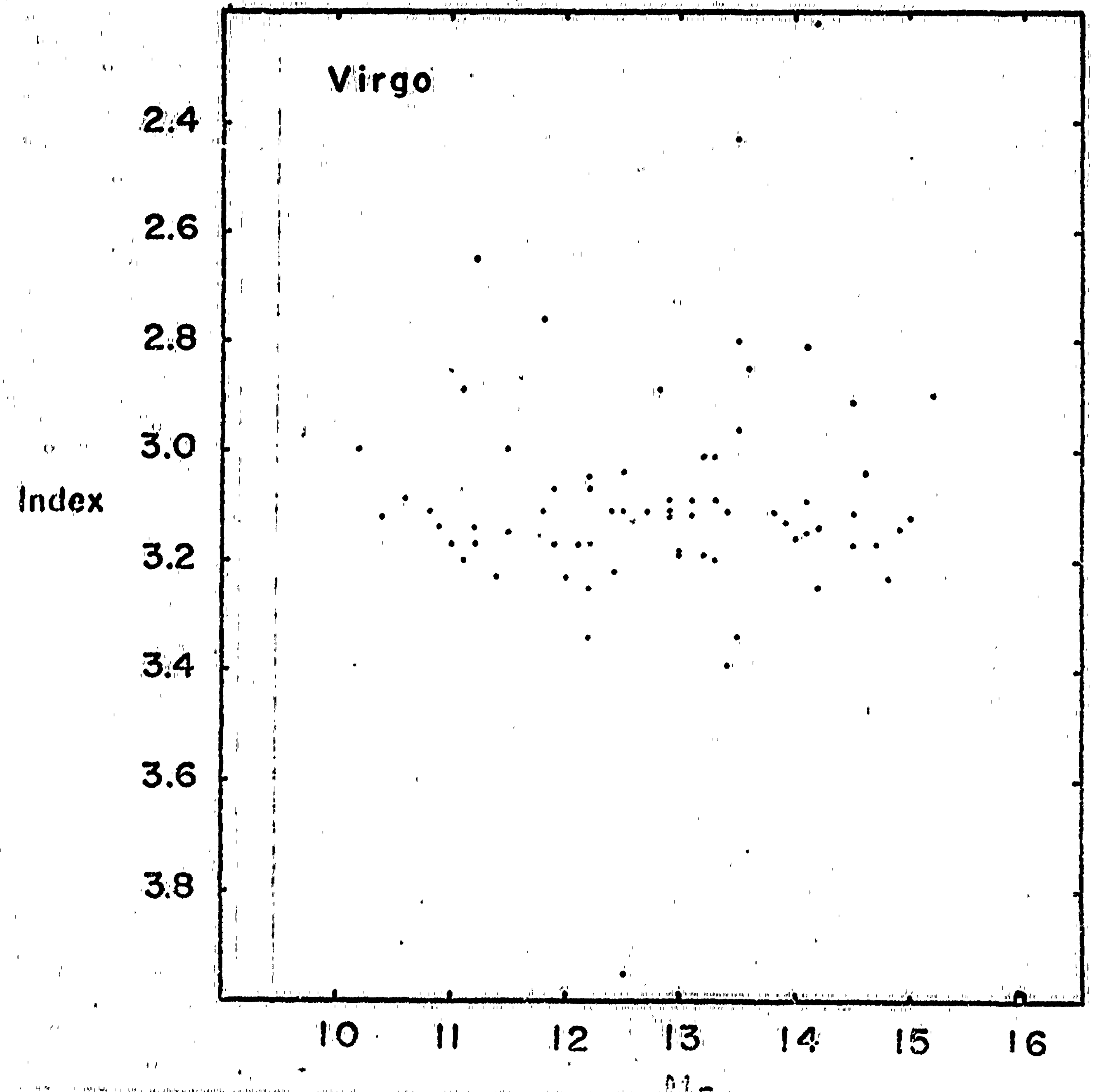
Index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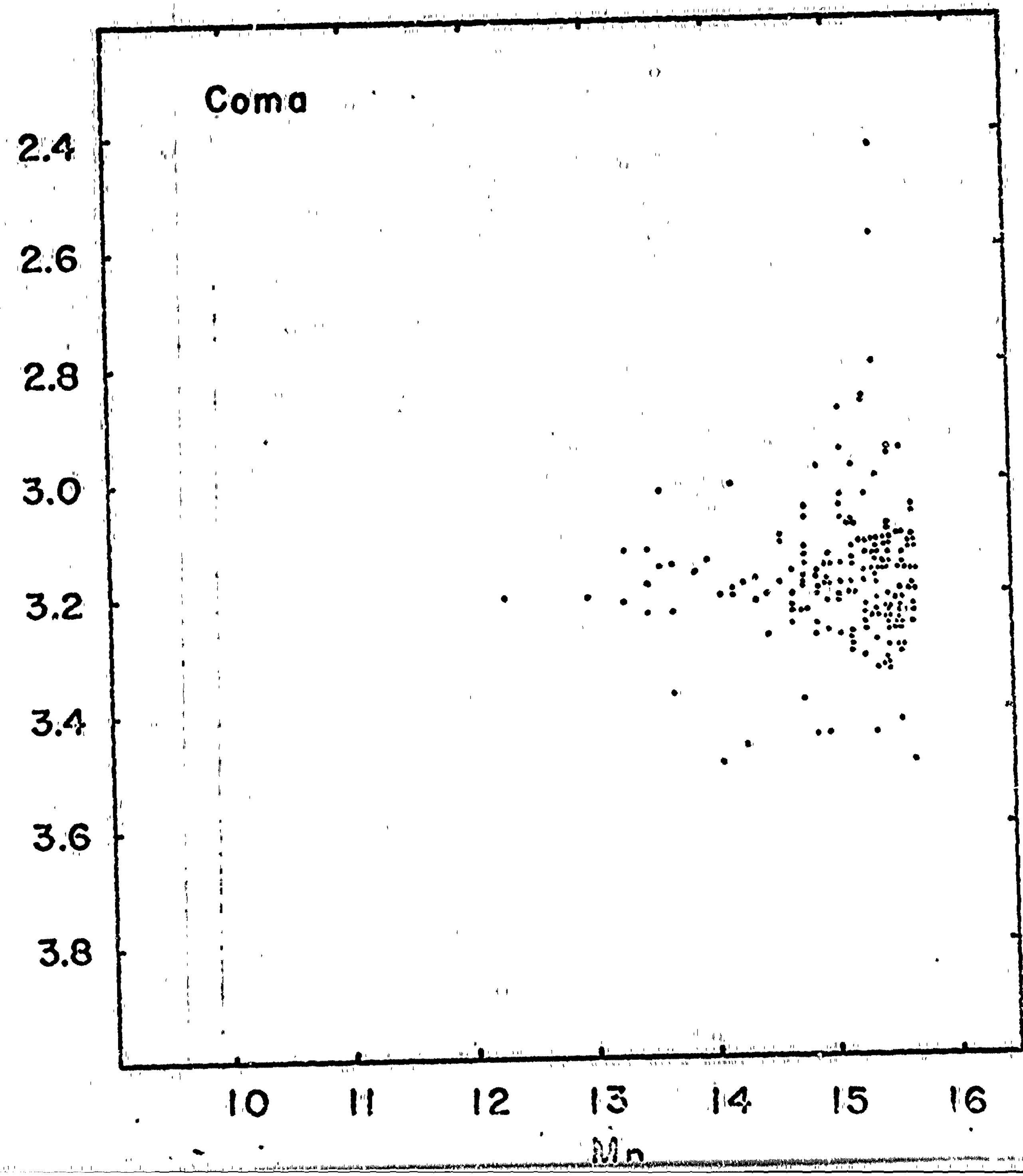

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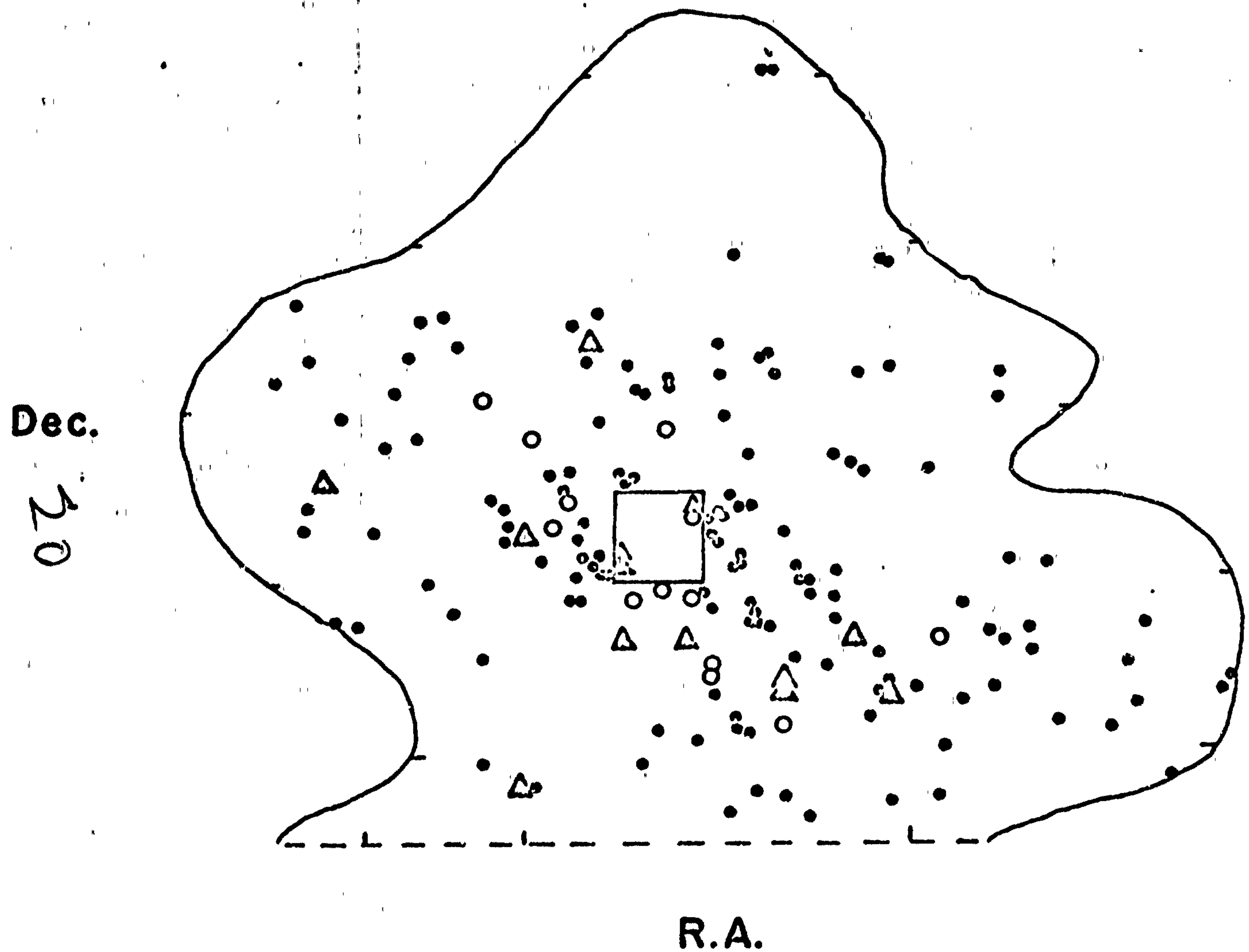

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